Niðurstöður sívirkrar vöktunar á óæskilegum efnum í sjávarfangi úr auðlindinni 2019 /

Undesirable substances in seafood – results from the Icelandic marine monitoring activities in the year 2019

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Ágrip á íslensku:	Í þessari skýrslu eru teknar saman niðurstöður vöktunar á óæskilegum efnum í ætum hluta sjávarfangs 2019. Vöktunin hófst árið 2003 fyrir tilstuðlan þáverandi Sjávarútvegsráðuneytis, núverandi Atvinnuvega- og nýsköpunar-ráðneytisins, og sá Matís ohf. um að safna gögnum og útgáfu á skýrslum vegna þessarar kerfisbundnu vöktunar á tímabilinu 2003-2012. Undanfarin ár hefur skort fjármagn til að halda áfram vinnu við þetta vöktunarverkefni og því var gert hlé á þessari mikilvægu gagnasöfnun sem og útgáfu niðurstaðna á tímabilinu 2013-2016. Verkefnið hófst aftur í mars 2017 en vegna fjárskorts nær það nú eingöngu yfir vöktun á óæskilegum efnum í ætum hluta sjávarfangs úr auðlindinni sem ætlað er til manneldis, en ekki fiskimjöl og lýsi fyrir fóður. Af sömu ástæðu voru ekki gerðar efnagreiningar á PAH, PBDE og PFC efnum í þetta sinn. Markmiðið með verkefninu er að sýna fram á stöðu íslenskra sjávarafurða m.t.t. öryggi og heilnæmis og nýta gögnin við gerð áhættumats á matvælum til að tryggja hagsmuni neytenda og lýðheilsu. Verkefnið byggir upp þekkingargrunn um magn óæskilegra efna í efnahagslega mikilvægum tegundum og sjávarafurðum, það er skilgreint sem langtímaverkefni þar sem útvíkkun og endurskoðun er stöðugt nauðsynlegt. Almennt voru niðurstöðurnar sem fengust 2019 í samræmi við fyrri niðurstöður frá árunum 2003 til 2012 sem og 2017 og 2018. Niðurstöðurnar sýndu að íslenskar sjávarafurðir innihalda óverulegt magn þrávirkra lífrænna efna s.s. díoxín, PCB og varnarefni. í þessari skýrslu voru hámarksgildi Evrópusambandsins (ESB) fyrir díoxín, díoxínlík PCB (DL-PCB) og ekki díoxínlík PCB (NDL-PCB) í matvælum samkvæmt reglugerð nr. 1259/2011 notuð til að meta hvernig íslenskar sjávarafurðir standast kröfur ESB. Niðurstöður ársins 2019 sýna að öll sýni af sjávarafurðum til manneldis voru vel undir hámarksgildum ESB fyrir þrávirk lífræn efni og þungmálma. Þá reyndist styrkur svokallaðra ICES6-PCB efna vera lágur í ætum hluta sjávarfangs, miðað við hámarksgildi ESB samkvæmt reglugerð nr. 1259/2011. Sömuleiðis sýndu niðurstöðurnar að styrkur þungmálma, t.d. kadmíum (Cd), blý (Pb) og kvikasilfur (Hg) í íslenskum sjávarafurðum var alltaf, nema í einu tilviki, undir hámarksgildum ESB.		
Lykilorð á íslensku:	*Sjávarfang, vöktun, Díoxín, díoxínlík PCB, PCB, varnarefni, þungmálmar, hámarksgildi, heilnæmi, lýðheilsa*		

Summary in English:	This report summarises the results obtained in 2019 for the screening of various undesirable substances in the edible part of Icelandic marine catches. The main aim of this project is to gather data and evaluate the status of Icelandic seafood products in terms of undesirable substances and to utilise the data to estimate the exposure of consumers to these substances from Icelandic seafood and risks related to public health. The surveillance programme began in 2003 and was carried out for ten consecutive years before it was interrupted. The project was revived in March 2017 to fill in gaps of knowledge regarding the level of undesirable substances in economically important marine catches for Icelandic export. Due to financial limitations the surveillance now only covers screening for undesirable substances in the edible portion of marine catches for human consumption and not feed or feed components. The limited financial resources have also required the analysis of PAHs, PBDEs and PFCs to be excluded from the surveillance, providing somewhat more limited information than in 2013. However, it is considered a long-term project where extension and revision is constantly necessary. In general, the results obtained in 2019 were in agreement with previous results on undesirable substances in the edible part of marine catches obtained in the monitoring years 2003 to 2012 and 2017 & 2018. In this report from the surveillance programme, the maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs (Regulation No 1259/2011) were used to evaluate how Icelandic seafood products measure up to limits currently in effect. The results show that in regard to the maximum levels set in the regulation, the edible parts of Icelandic seafood products contain negligible amounts of dioxins, dioxin like and non-dioxin-like PCBs. In fact, all samples of seafood analysed in 2019 were below EC maximum levels. Furthermore, the concentration of ICES6-PCBs was found to be low in the edible part of the marine catches, compared to the maximum limits set by the EU (Commission Regulation 1259/2011). The results also revealed that the concentrations of heavy metals, e.g. cadmium (Cd), lead (Pb) and mercury (Hg) in the edible part of marine catches were in all samples, except one, well below the maximum limits set by the EU.
English keywords:	*Marine catches, monitoring, dioxin, PCB, pesticides, heavy metals, maximum limits, human consumption, public health*

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1 Introduction

In 2003, the Icelandic Ministry of Fisheries, now the Ministry of Industries and Innovation, initiated a project aimed at screening for undesirable substances in the edible portion of marine catches, as well as in fish meal and fish oil for feed, captured in Icelandic waters. Matis was assigned the responsibility of carrying out the surveillance programme, which was on-going for ten consecutive years. In the period 2013-2016 this important collection of information and publication of the results was interrupted since Matis did not receive funding to work on this monitoring project. However, in March 2017 the surveillance programme was revived with funding from the Ministry of Industries and Innovation in Iceland to gather data and evaluate the status of Icelandic seafood products regarding undesirable substances, however, the current funding only covers screening for undesirable substances in the edible portion of marine catches for human consumption not feed or feed components. The project includes measurements on various undesirable substances in several economically important marine species from Icelandic fishing grounds in order to gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances. This report summarises results from the screening programme in the year 2019. The substances investigated in this monitoring project are: polychlorinated dibenzo dioxins and dibenzo furans (commonly called dioxins), dioxin-like polychlorinated biphenyls (PCBs), ICES-6 PCBs, 30 pesticides and breakdown products (i.e. HCB, DDTs, HCHs, dieldrin, endrin, chlordanes, toxaphenes and endosulfan substances), and inorganic trace elements such as heavy metals.

The purpose of this work is:

1. To gather information and evaluate the status of Icelandic seafood products in terms of undesirable substances.
2. Provide scientific evidence that Icelandic seafood products conform to regulations on seafood safety. That is, to evaluate how products measure up to limits currently in effect for inorganic trace elements, organic contaminants and pesticides in the EU (Commission regulation (EC) No 1881/2006 and its amendments).
3. To utilise the data gathered in this programme for a risk assessment and the setting of maximum values within EU & the European Economic Area (EEA) area, which are constantly being reviewed based on new data.

4. Provide independent scientific data on undesirable substances in Icelandic seafood for food authorities, fisheries authorities, industry, markets and consumers.

In this report the maximum levels for dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs are used to evaluate how Icelandic seafood products measure up to European commission (EC) limits currently in effect. The results obtained in the years 2003 to 2012, as well as 2017 and 2018, have already been published and are accessible at the Matis website (http://www.matis.is: Auðunsson, 2004, Ásmundsdóttir et al., 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Ásmundsdóttir et al., 2008, Jörundsdóttir et al., 2009, Jörundsdóttir et al., 2010a, Jörundsdóttir et al., 2010b, Baldursdóttir et al., 2011, Jörundsdóttir et al., 2012, Jensen et al., 2013, Jensen et al., 2018, Jensen et al. 2019). The above mentioned EU regulations have now been implemented (Reglugerð 265/2010) in the Icelandic legal framework regarding undesirable substances in food (Regulation (EC) No 1881/2006), which means that the maximum limits for undesirable substances in Icelandic seafood products are in line with the limits for these products in the EU member states.

2 Contaminants measured in the project

The following contaminants were measured in the edible parts of seafood and other seafood products for human consumption:

Dioxins, PCDD/Fs: Dioxins (dibenzo-p-dioxins) and dibensofurans (17 congeners according to WHO): 2.3.7.8-Tetra-CDD, 1.2.3.7.8-Penta-CDD, 1.2.3.4.7.8-Hexa-CDD, 1.2.3.6.7.8-Hexa-CDD, 1.2.3.7.8.9-Hexa-CDD, 1.2.3.4.6.7.8-Hepta-CDD, OCDD, 2.3.7.8-Tetra-CDF, 1.2.3.7.8-Penta-CDF, 2.3.4.7.8-Penta-CDF, 1.2.3.4.7.8-Hexa-CDF, 1.2.3.6.7.8-Hexa-CDF, 1.2.3.7.8.9-Hexa-CDF, 2.3.4.6.7.8-Hexa-CDF, 1.2.3.4.6.7.8-Hepta-CDF, 1.2.3.4.7.8.9-Hepta-CDF, OCDF.

Dioxin like PCB (12 congeners according to WHO):
non-ortho (CB-77, CB-81, CB-126, CB-169) and mono-ortho (CB-105, CB-114, CB-118, CB-123, CB-156, CB-157, CB-167, CB-189).

ICES-6-PCBs (6 congeners):
CB-28, CB-52, CB-101, CB-138, CB-153, CB-180.

Pesticides:
DDT-substances (6 congeners: pp-DDT, op-DDT, pp-DDD, op-DDD, pp-DDE and op-DDE), HCH-substances (4 isomers: α-, β-, γ-(Lindane), and δ-hexachlorocyclohexan), HCB, chlordanes (4 congeners and isomers: α- and γ-chlordane, oxychlordane and trans-nonachlor), toxaphenes (3 congeners, P 26, 50 and 62), aldrin, dieldrin, endrin, endosulfan (3 congeners and isomers: α- and β-endosulfan and endosulfansulfat) and heptachlor (3 congeners: heptachlor, cis-hepatchlorepoxid, trans-heptachlorepoxid).

Inorganic trace elements:
Hg (mercury), Cd (cadmium), Pb (lead), total As (organic and inorganic arsenic), chromium (Cr) and tin (Sn).

3 Sampling and analysis

3.1 Sampling

The collection of samples and the quality criteria for the analytical methods were in accordance with conditions set out by the EU for the information gathering campaign on dioxins and dioxin-like PCBs as well as for metals (Commission regulation 333/2007/EC, Commission regulation 2017/644/EC). The fish samples were collected by the Marine and Freshwater Research Institute (MRI) in Iceland and the Icelandic Food and Veterinary Authority (MAST) according to sampling protocols provided by Matis and the samples were kept frozen until preparation for analysis (see section 4.1.1). The copepod, krill and cod liver samples were also collected by MRI in Iceland. The copepod and krill are zooplankton that provide higher trophic levels (e.g. fish) with essential n-3 long-chain polyunsaturated fatty acids and are also highly sought after in the production of food supplements for human consumption. It is therefore important to monitor the amount of undesirable substances in these zooplankton.

Fishing grounds around Iceland are divided into five areas, as illustrated in Figure 1. All the samples were identified and labelled with the fishing area where they were caught.

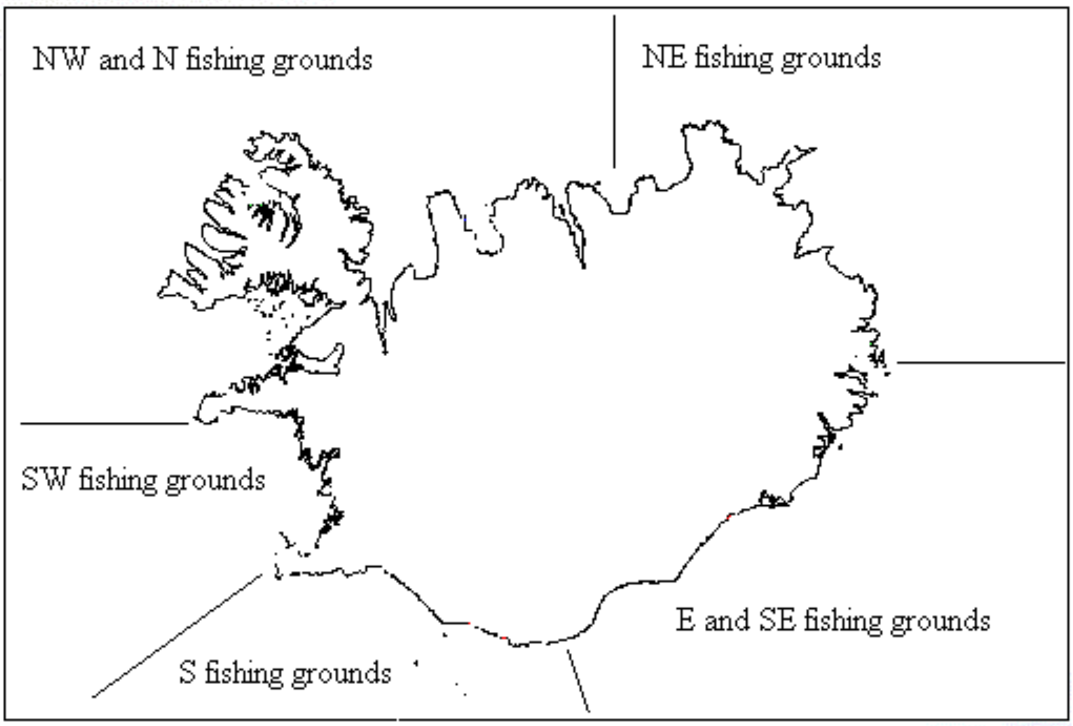

***Figure 1:** The division of the fishing grounds around Iceland used in this research.*

3.1.1 Sample preparation

All analyses were performed on the edible parts of the fish, while for the copepods, krill and cod liver samples the entire animal/organ was analysed. Each fish sample consisted of a pool from at least ten individuals of a specific length distribution, except for the monkfish and the spotted catfish, where the pool consisted of three and five individuals respectively. For details on length distribution and fishing grounds of the samples see Table 1 and 2 in the Appendix. Prior to sample preparation each fish was defrosted, after that the total weight and length of each individual fish was recorded as well as gender, gut weight and weight of fillets. The skinless fish fillets from the individuals were then pooled, homogenised and frozen again for analysis of organic contaminants or freeze-dried for heavy metal analysis. The cod liver sample consisted of a pooled sample from 10 individuals, the skinless fish fillets from these same 10 individuals were also pooled to prepare a composite sample of the edible fillets of this cod. The cod liver was removed from the cod soon after it was caught and placed in a pre-weighted acid rinsed glass container and frozen at sea. These cod livers were delivered frozen to the laboratory, where they were thawed, homogenised and pooled to prepare one composite sample.

For copepods and krill around 1 kg of the whole body of the animal was pooled and homogenised in a food blender prior to analysis.

3.2 Analyses

The heavy metal analysis of chrome, arsenic, tin, cadmium, mercury and lead was carried out at Matís. Inorganic contaminants in samples were determined by ICP-MS according to an accredited in-house method SV-25-02-SN in Matis Quality manual (modified NMKL 186 (2007) method). Matís is a National Reference Laboratory for heavy metal analysis in food and feed and has been taking part in various international inter-laboratory studies for many years.

The lipid content and organic contaminants were measured by Eurofins, Hamburg, Germany. Eurofins has taken part in an international inter-laboratory quality control study organised by WHO and EU and uses accredited methods for analysing dioxin, WHO-PCBs, ICES-6-PCBs, and pesticides.

All results are expressed as upper bond level, which means that when the concentration of a substance is measured to be below limit of detection (LOD) or limit of quantification (LOQ) of the analytical method, the concentration is set to be equal to the LOD/LOQ. In the case of dioxins and dioxin-like PCBs, the analytical data are converted to pg/g WHO-TEQ where the toxicity of each congener has been calculated using WHO-TEF (Toxic Equivalence Factor) based on the existing knowledge of its toxicity (Van den Berg et al., 1998). WHO-TEQ values have been adapted by the World Health Organization (WHO) in 1997 and by EU in its legislations. In 2005 the WHO-TEF values were re-evaluated based on existing toxicological data (Van den Berg et al., 2005, Haws et al., 2006) and expert judgment. These new TEF values have been established as the WHO-2005-TEQs for human risk assessment of the concerned compounds and have been implemented in the current EU legislation i.e. Commission Regulation (EU) No 1259/2011 for foodstuffs.

4 Results from monitoring of marine catches in Iceland

All results for undesirable substances from the surveillance programme in 2019 are listed in Tables 1-3 in the Appendix. The sections below contain an overview of the results obtained in samples of fish and other seafood products taken as part of the monitoring activities 2019.

4.1 Dioxins (PCDD/Fs) and dioxin like PCBs

4.1.1 Dioxins and dioxin like PCBs in seafood

All the species analysed contained dioxins (PCDD/PCDFs) below EU maximum limits (Figure 2 and Table 1 in the Appendix).

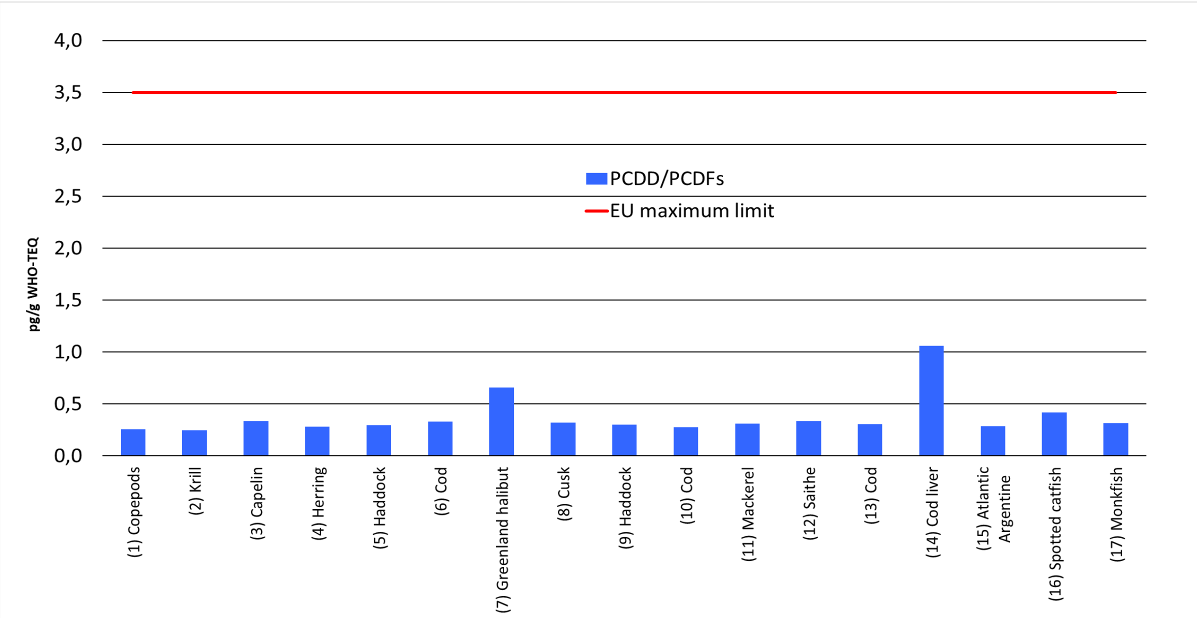

Figure 2: *Dioxins (PCDD/PCDFs) in the edible part of marine catches from Icelandic fishing grounds in 2019 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1 in the Appendix.*

As in previous years, a small difference was observed in the dioxin content between different marine species. The species that accumulate fat in the muscle, like for example Greenland halibut (sample no. 7), contain more dioxins than species which accumulate fat in the liver and thus have almost no fat in the muscle. This can be clearly seen for one of the cod samples (sample no. 13), where both the pooled skinless cod fillets (sample no. 13) and the cod livers (sample no. 14) from the same 10 individuals were analysed in two separate pooled samples. In this case, the dioxin content in the cod muscle was 0,305 pg/g WHO-TEQ compared to 1,06 pg/g WHO-TEQ in the cod liver i.e. the dioxin content is almost 3,5 times lower in the muscle meat than the liver.

In general, the level of dioxins in the edible part of the fish increases as the fat percentage in the muscle increases, but other important variables are age (size) and habitat. Greenland halibut can become quite old, which probably contributes considerably to the higher dioxins and dioxin-like PCBs values observed for this species, while Mackerel is high in fat content but does not become very old and therefore accumulates less dioxins over his lifetime (Table 1 in the Appendix). Figure 3 shows the sum of dioxins and dioxin-like PCBs in all samples analysed. All the species analysed contained total dioxins and dioxin-like PCBs below EU maximum limits (Figure 3 and Table 1 in the Appendix).

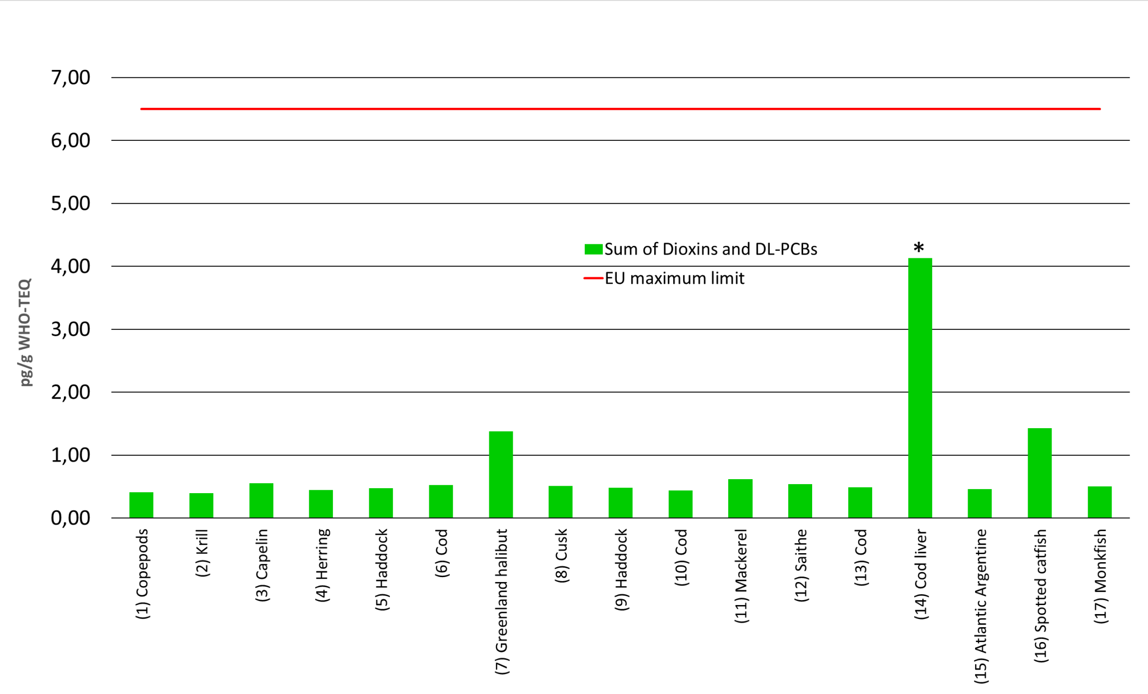

Figure 3: *Sum of dioxins and dioxin-like PCBs in the edible part of marine catches from Icelandic fishing grounds in 2019 in relation to maximum EU limit in WHO-TEQ pg/g wet weight. The number within parenthesis is the sample number indicated in Table 1 in the Appendix.*
**EU maximum limit for fish liver is 20 pg/g wet weight.*

The results show that the sum of dioxins and dioxin-like PCBs in the cod liver was considerably higher than in the muscle samples of the marine species analysed. However, the maximum limit set by the EU for this product is also considerably higher i.e. 20 pg/g WHO-TEQ wet weight compared to 6,5 pg/g WHO-TEQ wet weight for fish muscle and crustaceans. Therefore, the observed value, 4.13 pg/g WHO-TEQ for the cod liver is well below the limit set by the EU.

4.2 Marker PCBs

Marker PCBs have been used as indicators of the total PCB content or body burden of environmental biota, food and human tissue. The most frequent approach is to use either the total level of six or seven of the most commonly occurring PCBs. Nevertheless, the EU maximum limits are set for the sum concentration of ICES-6, i.e. CB-28, -52, -101, -138, -153 and -180 (Commission Regulation (EU) No 1259/2011). To enable comparison to earlier results, the sum of seven marker PCBs are presented in Table 1 in the Appendix, while the ICES-6 maximum limits are presented in Figure 4 to evaluate how Icelandic seafood products measure up to EU maximum limits.

4.2.1 ICES-6 PCBs in seafood

The results obtained for all of the Icelandic marine catches were well below the maximum limit set for non-dioxin-like PCBs i.e. the so-called ICES-6 (Figure 4).

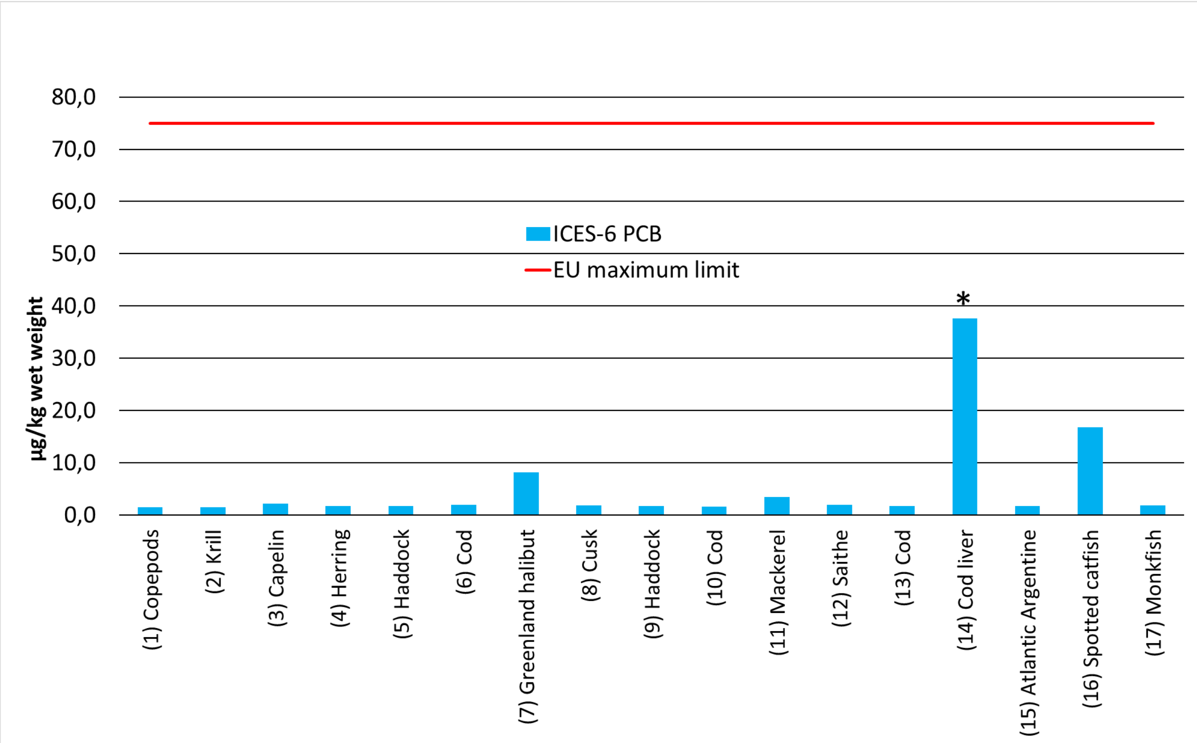

***Figure 4**: ICES-6 PCBs in marine catches from Iceland in 2019 (in µg/kg wet weight). Number in parenthesis is the sample number designated to each sample, see Table 1 in Appendix.*
**EU maximum limit for fish liver is 200 µg/kg wet weight.*

In this study, the highest total concentration for <u>the sum</u> of all six marker PCBs in the muscle samples was measured in spotted catfish (sample no. 16, Figure 4), a total of 16,8 µg/kg wet weight, the highest individual PCB congener measured in the catfish was PCB-153 with 8,04 µg/kg wet weight, or approximately half of the total. As for the dioxins and dioxin-like PCBs (section 4.1.1.), the highest concentrations of the ICES- 6 PCBs were found in species with higher lipid content in the muscle. Likewise, the ICES-6 PCB concentration was considerably higher in the cod liver sample than in the muscle samples analysed (Figure 4 and Table 1 in the Appendix). However, the EU maximum limit is also considerably higher (200 µg/kg wet weight) for fish liver than for the muscle meat of the other samples investigated.

For details, see Table 1 in the Appendix.

4.3 Polycyclic aromatic hydrocarbons (PAHs)

PAHs were not analysed in the samples this year. Results on PAHs in Icelandic seafood have been published in previous reports (Jörundsdóttir et al., 2010, Jensen et al., 2013).

4.4 Brominated flame retardants (BFRs)

BFRs have been accumulating in the environment over the last decade as their use in industry has increased. BFRs were not analysed in the samples this year. Results on BFRs in Icelandic seafood have been published in previous reports (Jensen et al., 2013).

4.5 Pesticides

In this section, the results for 12 different classes of pesticides are discussed. Results are shown in Table 2 in the Appendix.

In total 12 different pesticides or groups of pesticides were measured in the monitoring programme.

DDT (dichloro diphenyl trichloroethan) is probably the best-known insecticide. The technical product DDT is fundamentally composed of p,p'-DDT (80%) (Buser, 1995). DDT breaks down in nature, mostly to DDE but also to DDD. The concentration of DDT presented in this report is the sum of p,p'-DDT, o,p´-DDT, p,p'-DDE, o,p´-DDE, p,p´-DDD and o,p´-DDD.

HCH (hexachlorocyclohexan) is an insecticide which has been used since 1949. It is still produced and used in numerous countries, although it has been banned in many countries since the 1970s. Technical-grade HCH is a mixture of mainly four isomers: α-, β-, γ-(Lindane), and δ-HCH. Of these, only Lindane is an active substance comprising of approximately 15% of the total mixture, while α-HCH is 60-70% of the mixture. The Food and Agriculture Organization of the UN (FAO) has prohibited the use of the HCH mixture since in the 1980s, after that it was only allowed to use 99% pure Lindane. In this report the concentration of α-, β-, γ-(Lindane), and δ-HCH in the samples are reported.

HCB (hexachlorobenzene) is a fungicide, but it has also been used for industrial purpose and was e.g. produced in Germany until 1993. Today, HCB is mainly a by-product in different industrial processes such as production of pesticides but also from waste incineration and energy production from fossil fuel.

Chlordanes is a group of compounds and isomers where α- and γ-chlordane, oxychlordane and *trans*-nonachlor are the most common, but over 140 different chlordanes were produced from 1946 until 1988 when the production was banned. Chlordanes have been widely used all over the world as insecticides. In this report the concentration of chlordanes is reported as the sum of α-chlordane, γ-chlordane and oxychlordane. *Trans*-nonachlor is reported separately.

The **Toxaphenes** measured in the samples are the so-called parlar 26, 50 and 62. Toxaphene was used as an insecticide after the use of DDT was discontinued. Toxaphenes use was widespread and the toxaphene congeners are numerous. Several hundred have been analysed but they are thought to be tens of thousands. The substances measured, i.e. the parlar 26, 50 and 62, are the most common toxaphenes (about 25% of the total amount in nature) and these are used as indicators of toxaphene pollution. In this report the concentration of toxaphenes is reported as the sum of toxaphene 26, 50 and 62.

Aldrin and Dieldrin are widely used insecticides, but in plants and animals aldrin is transformed to dieldrin. Hence, the concentration of aldrin was below LOD in all the samples measured, while dieldrin was always above LOD. The maximum value in the EU is set for the sum of aldrin and dieldrin and the results are therefore presented as the sum of these two.

Two **Endosulfans** were measured, α- and β-endosulfan, as well as endosulfansulfat which is the breakdown product of endosulfan. Endosulfans are not as persistent as the other insecticides measured in this project. In this report the concentration of endosulfans is reported as the sum of α-endusulfan, β-endusulfan and endosulfansulfat. Other pesticides measured were **Endrin**, the sum of **Heptachlores** (cis-heptachlorepoxide, trans-heptachlorepoxide and heptachlor), **Pentachlorobenzene**, **Mirex** and **Octachlorostyrene**.

4.5.1 Pesticides in seafood

The results show that most of the pesticides measured in marine catches from Icelandic waters were below the limit of detection (see Table 2 in the Appendix). However, as mentioned before the results are expressed as upper bond, and therefore the results presented are likely to be an overestimation. HCB and *trans*-Nonachlor were detected in about half of the species analysed, whilst α- β-, γ- and δ-HCHs were almost always below LOQ. Figure 5 shows the level of total DDT in the different marine catches, while Figure 6 shows the level of HCB in the same samples.

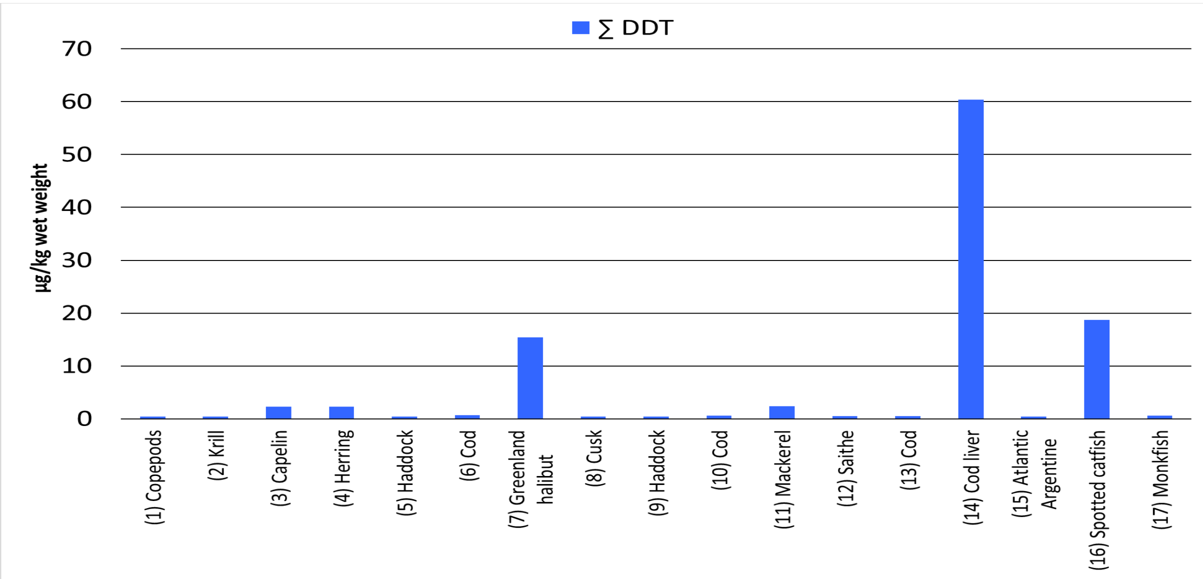

Figure 5: *∑DDT in marine catches from Icelandic fishing grounds in 2019 in µg/kg wet weight.*

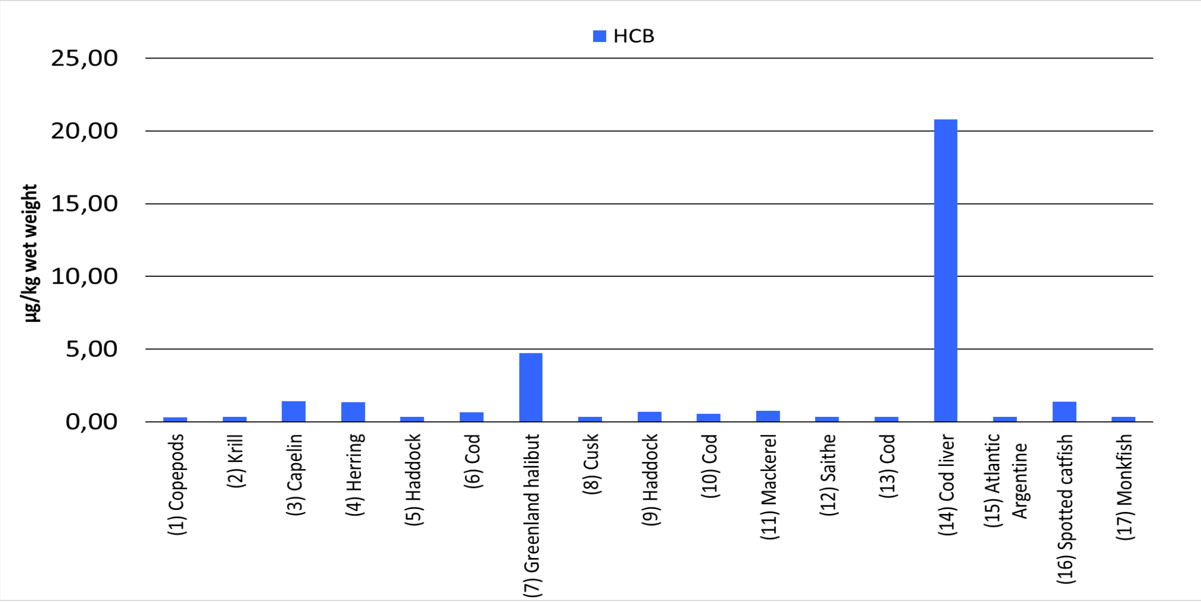

Figure 6: *HCB in marine catches from Icelandic fishing grounds in 2019 in µg/kg wet weight.*

No limits have yet been set for pesticides in seafood, but to enable comparison with earlier measurements presented in previous reports from this project (Jensen, et al. 2013, Jensen, et al. 2018 & Jensen, et al. 2019), the results of ∑DDT and HCB are presented from the monitoring in 2019. In general, the concentration of pesticides is higher in Icelandic marine catches with a higher lipid content (Table 2 in Appendix).

4.6 Inorganic trace elements

Inorganic trace elements were analysed in all samples from the year 2019. The following inorganic trace elements were analysed: Hg (mercury), Cd (cadmium), Pb (lead), As (arsenic), Sn (tin) and Cr (chromium). As mentioned before, the results are expressed as upper bond and therefore the results presented are likely to be an overestimation. All results for the analysed trace elements are reported in Table 3 in the Appendix.

4.6.1 Inorganic trace elements in seafood

In short, the concentration of the heavy metals Hg, Pb and Cd in all samples consisting of the edible part of fish and the cod liver were well below the maximum limits set by EU (Commission regulation (EC) No 1881/2006 and its amendments). Maximum limits set by the EU (Commission regulation 1881/2006) for tin (Sn) only apply to canned food products and no maximum limits exist in the EU for tin (Sn) in fish or fishery products. The concentration of tin (Sn) in all the samples analysed was very low as can be seen in Table 3 in the Appendix; in fact, no sample contained tin in concentrations above limits of detection.

The concentration of mercury (Hg) in the marine catches is shown in Figure 7.

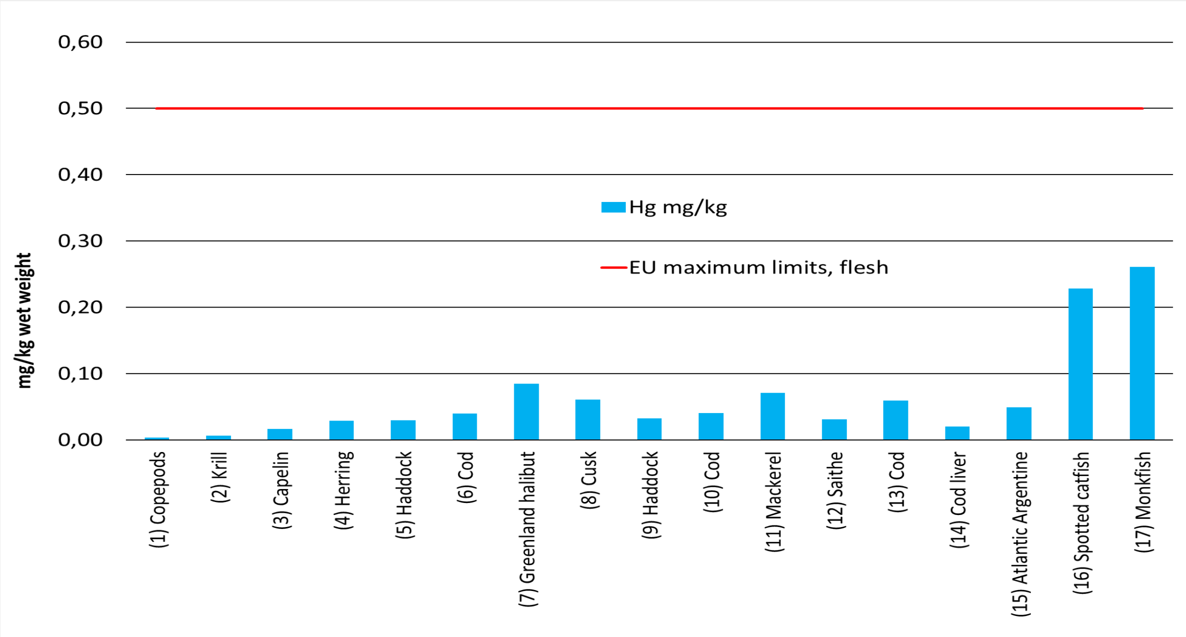

Figure 7: *Mercury (Hg) in marine catches from Icelandic fishing grounds in 2019 in mg/kg wet weight.*

The concentration of lead (Pb) in all the samples of marine catches was very low as can be seen in Figure 8 and Table 3 in the Appendix; in fact the concentration of lead was below limits of detection for all samples.

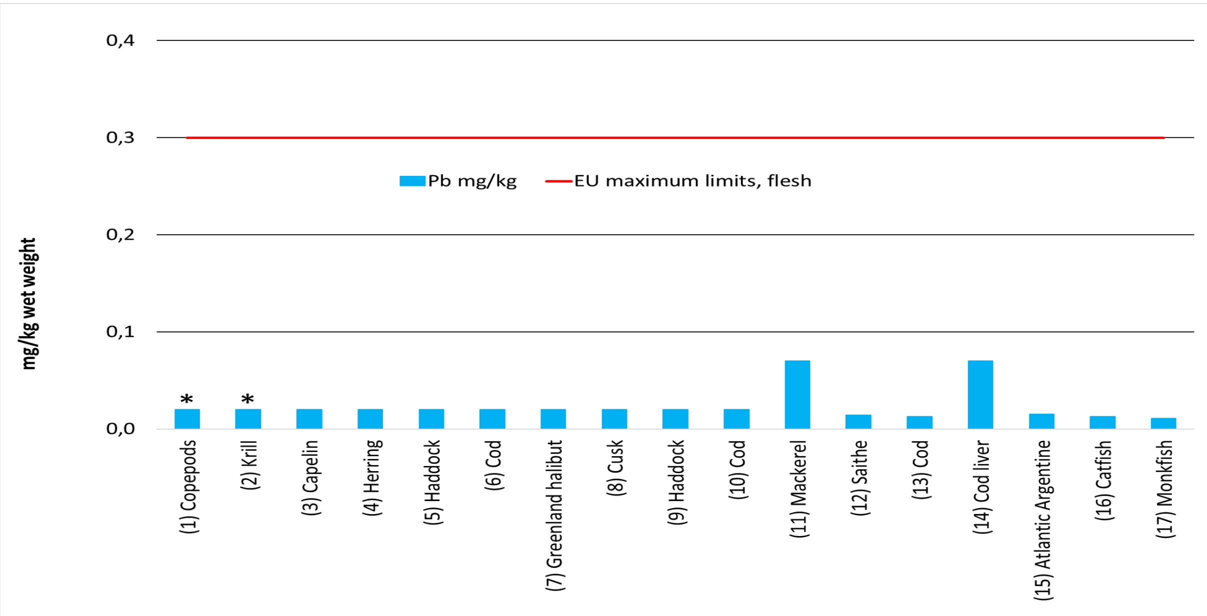

Figure 8: *Lead (Pb) in marine catches from Icelandic fishing grounds in 2019 in mg/kg wet weight.*
**EU maximum limit for lead in crustaceans is set to 0,5 mg/kg wet weight.*
§EU maximum limit for Pb does not apply to cod liver since it is set for muscle meat of fish.

The concentration of cadmium (Cd) in the marine catches was generally very low as can be seen in Figure 9 and Table 3 in the Appendix. The only sample that contained cadmium in concentration above EU maximum limits were copepods (sample no. 1). The EU maximum limit for cadmium in crustaceans is set to 0,5 mg/kg wet weight. The EU maximum limit for Cd shown in Figure 9 does not apply to cod liver since it is set for muscle meat of fish and is therefore not applicable for cod liver.

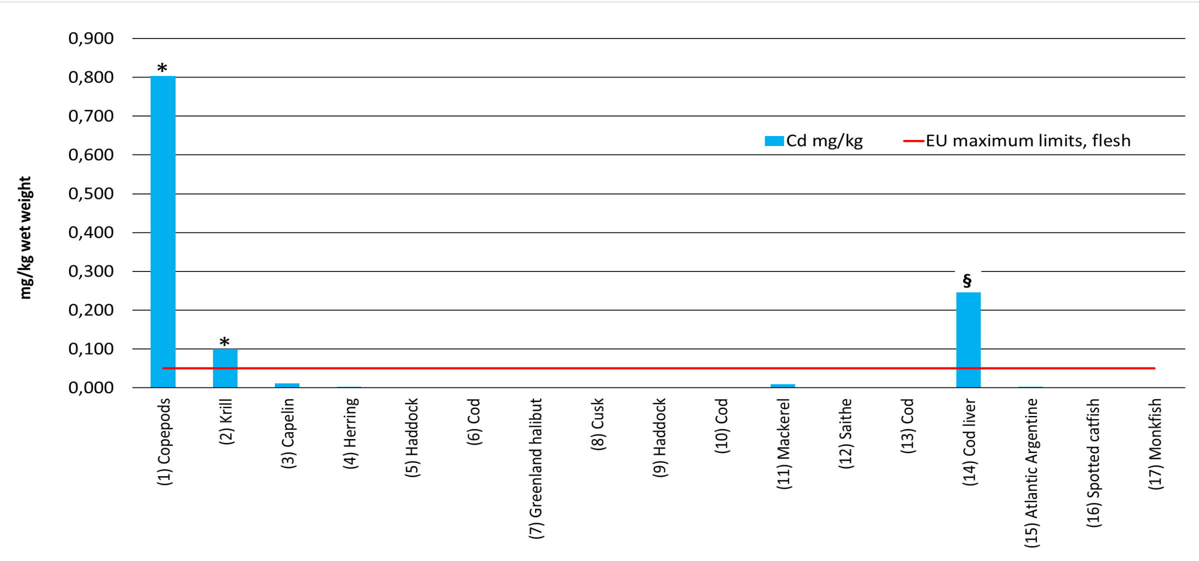

Figure 9: *Cadmium (Cd) in marine catches from Icelandic fishing grounds in 2019 in mg/kg wet weight.*
**EU maximum limit for cadmium in crustaceans is set to 0,5 mg/kg wet weight.*
§EU maximum limit for Cd does not apply to cod liver since it is set for muscle meat of fish.

No limits have yet been set for arsenic in foodstuffs, but results from the monitoring in 2019, which are shown in Figure 10 were in agreement with earlier measurements (Auðunsson, 2004, Ásmundsdóttir et al. 2005, Ásmundsdóttir and Gunnlaugsdóttir, 2006, Jörundsdóttir et al., 2009, Baldursdóttir et al, 2011, Jörundsdóttir et al., 2012, Jensen et al., 2013, Jensen et al., 2018 & Jensen et al., 2019). The highest levels of As (above 7 mg/kg) were found in the haddock samples (sample no. 5 & 9) and the spotted catfish (sample no. 16) as seen in Figure 10. Different from the results from 2018 (Jensen et al., 2019) all samples investigated 2019 contained arsenic below 10 mg/kg. The total arsenic concentration was measured in the samples, but not the concentration of the toxic form i.e. inorganic arsenic.

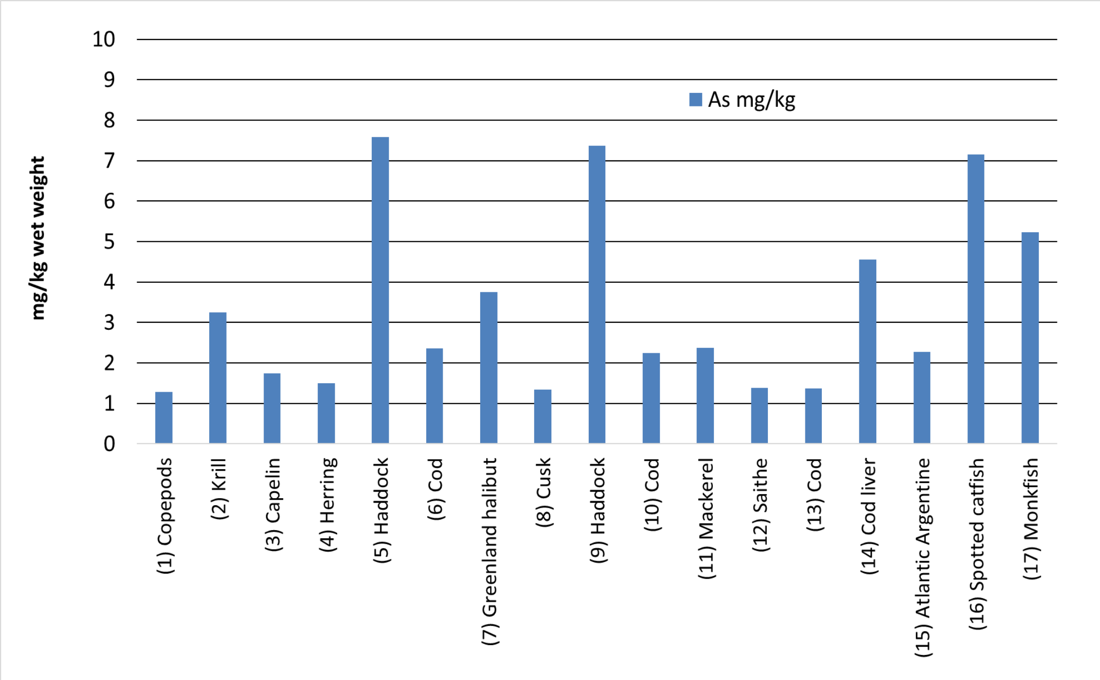

Figure 10: *Arsenic (As) in marine catches from Icelandic fishing grounds in 2019 in mg/kg wet weight.*

5 Acknowledgements

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Commission Regulation (EC) No 1881/2006 um hámarksgildi fyrir tiltekin aðskotaefni í matvælum, 19th of December 2006

Reglugerð Nr 265/2010 um gildistöku reglugerðar framkvæmdastjórnarinnar (EB) nr. 1881/2006 um hámarksgildi fyrir tiltekin aðskotaefni í matvælum.

7 Appendix

Table 1: Dioxins PCBs and PBDE in fish muscle and one cod liver sample on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fishing ground	Size [cm]	Lipid content %	PCDD/PCDFs pg/g WHO-TEQ	Dioxin like PCBs pg/g WHO-TEQ	Sum of Dioxins and DL-PCBs pg/g WHO-TEQ	Marker PCBs µg/kg	ICES-6 PCB µg/kg
R1900663-1	1	Copepods	*Calanus finmarchicus*	*NE*	-	2,9	0,26	0,15	0,41	1,5	1,5
R1900663-2	2	Krill	*Euphausia*	*S*	-	1,2	0,25	0,15	0,40	1,5	1,4
R1900663-3	3	Capelin	*Mallotus villosus*	*S*	15-25	10,4	0,34	0,21	0,55	2,4	2,2
R1900663-4	4	Herring	*Clupea harengus*	*S*	25-35	10	0,28	0,17	0,45	1,9	1,8
R1900663-5	5	Haddock	*Melanogrammus aeglefinus*	*NW & N*	40-50	0,5	0,29	0,18	0,47	1,7	1,7
R1900663-6	6	Cod	*Gadus morhua*	*E & SE*	50-60	0,7	0,33	0,20	0,53	1,9	2,0
R1900663-7	7	Greenland halibut	*Reinhardtius hippoglossoides*	*E & SE*	45-60	13,8	0,66	0,72	1,38	9,5	8,2
R1900663-8	8	Cusk	*Brosme brosme*	*E & SE*	40-50	0,5	0,32	0,19	0,51	1,9	1,9
R1900663-9	9	Haddock	*Melanogrammus aeglefinus*	*S*	50-60	0,5	0,30	0,18	0,48	1,8	1,8
R1900663-10	10	Cod	*Gadus morhua*	*S*	60-70	0,9	0,27	0,17	0,44	1,6	1,6
R1901903-1	11	Mackerel	*Scomber scrombus*	*S*	35-40	20,5	0,31	0,30	0,62	3,8	3,4
R1902698-1	12	Saithe	*Pollachius virens*	*SA*	60-70	1,1	0,34	0,20	0,54	2,0	2,0
R1902698-2	13	Cod	*Gadus morhua*	*E & SE*	50-60	0,7	0,31	0,18	0,49	1,8	1,8
R1902698-3	14	Cod liver	*Gadus morhua*	*E & SE*	-	59,7	1,06	3,06	4,13	43,3	37,6
R1902698-4	15	Atlantic Argentine	*Argentina silus*		30-40	0,8	0,29	0,17	0,46	1,7	1,7
R1902698-5	16	Spotted catfish	*Anarhichas minor*	*NW & W*	45-75	3,4	0,42	1,02	1,43	18,7	16,8
R1902698-6	17	Monkfish	*Lophius piscatorius*	-	68-97	0,5	0,31	0,19	0,50	1,9	1,8
		EU maximum limits ‡					3,50	*	6,50	*	75

*No maximum limits exist in the EU for the substances

n.a. Not analysed

PCDD/PCDFs are 2,3,7,5,8-PCDDs and PCDFs.

DL-PCBs are CB-77, -81, -126, -169, -105, -114, -118, -123, -156, -157, -167 and -189

Marker PCBs are CB-28, -52, -101, -118, -138, -153 and -180

PBDEs are BDE-170, -28, -47, -49, -66, -71, -85, --99, -100, -119, -126, -138, -153, -154, -183, -184, -196, -197, -206 and -207. BDE-209 was not detected in any sample.

‡ Maximum level for non dioxin like PCBs, i.e. Marker PCBs excluding CB-118

Table 2: Pesticides in fish mucle and one cod liver sample on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fishing ground	Size [cm]	Lipid content %	α-HCH µg/kg	β-HCH µg/kg	δ-HCH µg/kg	γ-HCH µg/kg	Σ DDT µg/kg	Pentachlor benzene µg/kg	HCB µg/kg	Σ Heptachlores µg/kg
R1900663-1	1	Copepods	*Calanus finmarchicus*	*NE*	-	2,9	<0,152	<0,152	<0,152	<0,152	0,44	<0,303	<0,303	0,33
R1900663-2	2	Krill	*Euphausia*	*S*	-	1,2	<0,164	<0,164	<0,164	<0,164	0,45	<0,329	<0,329	0,36
R1900663-3	3	Capelin	*Mallotus villosus*	*S*	15-25	10	<0,167	<0,167	<0,167	<0,167	2,27	<0,333	1,42	0,56
R1900663-4	4	Herring	*Clupea harengus*	*S*	25-35	10	<0,158	<0,158	<0,158	<0,158	2,26	<0,316	1,35	0,48
R1900663-5	5	Haddock	*Melanogrammus aeglefinus*	*NW & N*	40-50	0,5	<0,175	<0,175	<0,175	<0,175	0,42	<0,35	<0,35	0,38
R1900663-6	6	Cod	*Gadus morhua*	*E & SE*	50-60	0,7	<0,159	<0,159	<0,159	<0,159	0,69	<0,318	0,67	0,35
R1900663-7	7	Greenland halibut	*Reinhardtius hippoglossoides*	*E & SE*	45-60	13,8	0,39	<0,167	<0,167	<0,167	15,4	0,57	4,73	0,70
R1900663-8	8	Cusk	*Brosme brosme*	*E & SE*	40-50	0,5	<0,17	<0,17	<0,17	<0,17	0,43	<0,34	<0,34	0,37
R1900663-9	9	Haddock	*Melanogrammus aeglefinus*	*S*	50-60	0,5	<0,174	<0,174	<0,174	<0,174	0,42	0,35	0,67	0,38
R1900663-10	10	Cod	*Gadus morhua*	*S*	60-70	0,9	<0,16	<0,16	<0,16	<0,16	0,57	<0,321	0,54	0,35
R1901903-1	11	Mackerel	*Scomber scrombus*	*S*	35-40	20,5	0,22	<0,164	<0,164	<0,164	2,39	0,33	0,75	0,46
R1902698-1	12	Saithe	*Pollachius virens*	*SA*	60-70	1,1	<0,172	<0,172	<0,172	<0,172	0,53	<0,345	<0,345	0,31
R1902698-2	13	Cod	*Gadus morhua*	*E & SE*	50-60	0,7	<0,163	<0,163	<0,163	<0,163	0,47	<0,327	<0,327	0,36
R1902698-3	14	Cod liver	*Gadus morhua*	*E & SE*	-	59,7	1,62	<0,5	<0,5	<0,5	60,4	1,87	20,8	3,61
R1902698-4	15	Atlantic Argentine	*Argentina silus*	-	30-40	0,8	<0,162	<0,162	<0,162	<0,162	0,45	<0,325	<0,325	0,36
R1902698-5	16	Spotted catfish	*Anarhichas minor*	*NW & W*	45-75	3,4	<0,159	<0,159	<0,159	<0,159	18,8	<0,318	1,39	0,57
R1902698-6	17	Monkfish	*Lophius piscatorius*	-	68-97	0,5	<0,167	<0,167	<0,167	<0,167	0,64	<0,333	<0,333	0,37
		EU maximum limits												

Table 2 (cont): Pesticides in fish muscle and one cod liver sample on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Fishing ground	Size [cm]	Lipid content %	Aldrin/ dieldrin µg/kg	Toxaphene µg/kg	Octachloro styrene µg/kg	Endrin µg/kg	Endo-sulfane µg/kg	Chlordane µg/kg	*trans*-Nonachlor µg/kg	Mirex µg/kg
R1900663-1	1	Copepods	*Calanus finmarchicus*	*NE*	-	2,9	0,3	1,2	<0,0303	<0,182	0,79	0,43	0,06	<0,0606
R1900663-2	2	Krill	*Euphausia*	*S*	-	1,2	0,2	1,3	<0,0329	<0,197	0,86	0,46	<0,0329	<0,0658
R1900663-3	3	Capelin	*Mallotus villosus*	*S*	15-25	10	2,1	3,7	0,04	<0,2	0,87	0,92	0,58	<0,0667
R1900663-4	4	Herring	*Clupea harengus*	*S*	25-35	10	1,5	3,2	<0,0317	<0,19	0,82	0,84	0,53	<0,0633
R1900663-5	5	Haddock	*Melanogrammus aeglefinus*	*NW & N*	40-50	0,5	0,2	1,4	<0,035	<0,21	0,91	0,49	<0,035	<0,0699
R1900663-6	6	Cod	*Gadus morhua*	*E & SE*	50-60	0,7	0,3	1,3	<0,0394	<0,191	0,83	0,53	0,16	<0,0637
R1900663-7	7	Greenland halibut	*Reinhardtius hippoglossoides*	*E & SE*	45-60	14	2,7	12	0,17	0,79	0,87	3,28	3,66	0,24
R1900663-8	8	Cusk	*Brosme brosme*	*E & SE*	40-50	0,5	0,2	1,4	<0,034	<0,204	0,88	0,48	0,05	<0,068
R1900663-9	9	Haddock	*Melanogrammus aeglefinus*	*S*	50-60	0,5	0,2	1,4	<0,0347	<0,208	0,90	0,49	<0,0347	<0,0694
R1900663-10	10	Cod	*Gadus morhua*	*S*	60-70	0,9	0,5	1,3	<0,0321	<0,192	0,83	0,49	0,12	<0,0641
R1901903-1	11	Mackerel	*Scomber scrombus*	*S*	35-40	20,5	0,9	2,6	<0,0329	0,22	0,86	0,73	0,45	<0,0658
R1902698-1	12	Saithe	*Pollachius virens*	*SA*	60-70	1,1	0,2	1,4	<0,0345	<0,207	0,90	0,49	<0,0575	<0,069
R1902698-2	13	Cod	*Gadus morhua*	*E & SE*	50-60	0,7	0,2	1,3	<0,0327	<0,196	0,85	0,46	<0,0454	<0,0654
R1902698-3	14	Cod liver	*Gadus morhua*	*E & SE*	-	59,7	18	49	0,76	1,82	3,49	27,5	20,0	0,67
R1902698-4	15	Atlantic Argentine	*Argentina silus*	-	30-40	0,8	0,2	1,3	<0,0325	<0,195	0,85	0,45	<0,0325	<0,0649
R1902698-5	16	Spotted catfish	*Anarhichas minor*	*NW & W*	45-75	3,4	2,3	8,6	0,09	0,33	0,90	2,06	3,90	0,39
R1902698-6	17	Monkfish	*Lophius piscatorius*	-	68-97	0,5	0,2	1,3	<0,0333	<0,2	0,87	0,47	<0,0333	<0,0667
		EU maximum limits					50			50				

Table 3: Trace elements in fish muscle on wet weight

Sample code	Fish sample no.	Sample name	Latin name	Cr mg/kg	As mg/kg	Cd mg/kg	Sn mg/kg	Hg mg/kg	Pb mg/kg
R1900663-1	1	Copepods	*Calanus finmarchicus*	0,018	1	0,803	<0,002	<0,004	<0,02
R1900663-2	2	Krill	*Euphausia*	<0,01	3,3	0,100	<0,002	0,01	<0,02
R1900663-3	3	Capelin	*Mallotus villosus*	0,038	1,7	0,011	<0,003	0,017	<0,02
R1900663-4	4	Herring	*Clupea harengus*	<0,02	1,5	0,003	<0,003	0,029	<0,02
R1900663-5	5	Haddock	*Melanogrammus aeglefinus*	0,016	7,6	<0,0004	<0,002	0,030	<0,02
R1900663-6	6	Cod	*Gadus morhua*	0,026	2,4	<0,0004	<0,002	0,04	<0,02
R1900663-7	7	Greenland halibut	*Reinhardtius hippoglossoides*	<0,02	3,8	0,0013	<0,003	0,085	<0,02
R1900663-8	8	Cusk	*Brosme brosme*	<0,01	1,3	<0,0004	<0,002	0,061	<0,02
R1900663-9	9	Haddock	*Melanogrammus aeglefinus*	<0,01	7,4	<0,0004	<0,002	0,03	<0,02
R1900663-10	10	Cod	*Gadus morhua*	<0,01	2,2	<0,0004	<0,002	0,04	<0,02
R1901903-1	11	Mackerel	*Scomber scrombus*	<0,06	2,4	0,0097	<0,01	0,071	<0,07
R1902698-1	12	Saithe	*Pollachius virens*	0,034	1,4	0,0007	<0,002	0,031	<0,014
R1902698-2	13	Cod	*Gadus morhua*	0,011	1,4	0,0013	<0,002	0,060	<0,013
R1902698-3	14	Cod liver	*Gadus morhua*	<0,06	4,6	0,2460	<0,01	<0,02	<0,07
R1902698-4	15	Atlantic Argentine	*Argentina silus*	0,021	2,3	0,0022	<0,002	0,049	<0,015
R1902698-5	16	Spotted catfish	*Anarhichas minor*	<0,01	7,1	0,0011	<0,002	0,228	<0,013
R1902698-6	17	Monkfish	*Lophius piscatorius*	0,004	5,2	<0,0003	<0,002	0,261	<0,011
		EU maximum limits, flesh				0,05		0,5	0,3